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ABSTRACT

This report describes a multivariate analysis technique that approaches the problems of educational production function analysis by (1) using comparable measures of output across large experiments, (2) accounting systematically for differences in socioeconomic background, and (3) treating the school as a complete system in which different experiments can be related to each other. Multivariate analysis provides (1) a useful perspective for organizing educational research, (2) an accurate information source for describing American education, and (3) a framework for planning future research. Included in this paper are a review and an annotated listing of various multivariate studies, some implications of multivariate analysis for future research, and a list of 31 references. (Author/LLR)

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MULTIVARIATE ANALYSIS OF SCHOOLS AND EDUCATIONAL POLICY

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PREFACE

This paper presents a revised version of a report prepared for the Office of the Assistant Secretary for Program Evaluation, Department of Health, Education, and Welfare, during the summer of 1970. The impetus for the paper was generated by a seminar conducted by the author at The Rand Corporation in the spring of that year.

The author wishes to thank four Rand colleagues who took time to read carefully, and to comment on, the manuscript: Harvey Averch, M. B. (Polly) Carpenter, John Pincus, and Marjorie Rapp. Thanks go also to Suzanne Mennine who rendered helpful editorial assistance.

SUMMARY

Although the value of accurately estimated educational production functions would be considerable, such a feat is not possible in terms of currently available knowledge and data on the educational process, and probably not obtainable in the near future. It is therefore heroic to use the production function ideal as a standard against which to judge current analytical contributions to the educational research field. Data limitations that make production function estimation the frustrating problem that it is today include the following inadequacies:

1. Too few technologies have been quantified;
2. Erroneous variables, or inadequate proxies, have been available;
3. Non-longitudinal data have limited model specifications;
4. Lack of independent variance between variables has hampered results;
5. Inability to place schools on the efficiency frontier has resulted from our ignorance about the factors that constitute efficiency;
6. Simultaneity, the existence of simultaneous relationships affecting learning, cannot be neglected;
7. Aggregation of data causes problems because of the danger of lessening data variances.

But it is the contention of this paper that multivariate analysis can yield important insights into the American educational process, that it can do so now, and that it can do so in the presence of all or most of the difficulties outlined above.

Although it may sacrifice some experimental precision in methodology, the multivariate approach outlined here comes to grips with the problems of educational production function analysis by means of the following techniques:

1. Using comparable measures of output across large experiments;
2. Accounting systematically for differences in socioeconomic background;
3. Treating the school as a complete system in which different experiments can be related to each other.

These techniques, and especially the first two, differentiate the multivariate work discussed here from other work. What kinds of results can we expect from this work? At least three can be listed. First, the findings provide a useful perspective for organizing educational research. Second, this approach has given us valuable information toward a meaningful description of American education. Third, the approach provides us with a convenient framework within which to plan for future research.

We can gain an accurate indication of interactions between such variables as teacher experience, class size, and the like from experiments with linear and log-linear models. We can learn from the cognitive tests of basic skills what our society wishes children to learn. Knowing the types of inputs that seem to be associated with success within the present technology is important for suggesting direction. For example, analysis already conducted leads us to the tentative hypothesis that reliance on teacher experience and formal education alone as a way of improving educational quality is inefficient; it would be better to recruit intelligent teachers, and to engage in more planning and on-the-job teacher training. The variables that we now have are of more value than has been suggested when examining broad educational policy questions. Although longitudinal data is vital for meaningful description of relationships in American education, much can be achieved for broad policy insights by cross-sectional data, when supplemented with other knowledge.

Some fifteen studies employing multivariate techniques have already been conducted. These contain useful information that can be summarized under the following topics:

1. The importance of environment to educational success;
2. The characteristics of the school, such as administration, funding integration, facilities, and the teachers as related to pupil performance;
3. The implications of this information for future American education.

Although American education has dealt adequately with the problems of the past twenty-five years, it has faltered in flexibility, and that

has been expensive. Let us restate the arguments to support this view.

The traditional technology has been too exclusively involved with the importance of the classroom teacher, who, utilizing group instruction in the self-contained classroom, has been unable to cope well with the needs of atypical students. One possible solution to these difficulties, reducing class size, does not seem viable. Further, the incentive-reward structure for the teachers, the school system's only input, has been unsuccessful. Finally, since the number of college hours completed by teachers is seldom related to the performance of their pupils, something seems amiss in their training.

This construct seems that which is most consistent with the findings in the multivariate studies reviewed in this paper. Some obvious directions for public educational policy are suggested. We need to look at new organizational design, teamwork, and studies to determine what it is about teacher and manager skills that relates to pupil performance. We need to develop objective measures of performance other than cognitive test scores if we are to come to grips with measuring the results that our schools and communities wish to accomplish. We need to think about the levels upon which to conduct educational research and development. In the past, what direction there has been came from the universities. But work there has not focused directly on questions of interest to the policymaker. It is the place of the Federal government to provide central direction, performing this role through a National Institute of Education, maintaining liaison with, but not a part of, the research activities of the Office of Education. Through this means, research could be carried out that might, in time, allow us to come close to definition of educational production functions.

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I. THE PRODUCTION FUNCTION AS AN ANALYTICAL TECHNIQUE

In recent years there has been considerable interest among educational researchers in an analytical technique for relating school inputs to objective performance measures which has come to be known as "production function" analysis. After some early optimism concerning the potential of the approach, researchers began to see more clearly the limitations imposed by the data available to them. The pessimism which resulted is probably well grounded from the standpoint of "solving" educational technology, but there is less justification for a concomitant tendency on the part of researchers to overlook some important inferences which can be obtained using such models and data as are available.

In this paper I hope to show that social scientists have been overambitious even to discuss their research in terms of educational production functions. At the same time, my purpose is to demonstrate that considerable insight into the workings of the American educational structure can be obtained with less ambitious multivariate models which take pupil socioeconomic background and educational policy variables into account. The paper includes a discussion of the direction I think educational research should take in the future, and the role of the Federal government in those efforts.

THE CONCEPT OF A PRODUCTION FUNCTION

The *production function* is one of the more important concepts available to the economist in his study of the firm. Simply stated, a production function is a statement of all combinations of inputs, physical and human, meaningfully classified, which, when used as efficiently as possible, will produce a given level of output. A ton of steel, for example, can be produced by many workers using small open hearths, or by few workers and large open hearth furnaces, or oxygen furnaces or a Bessemer process. This production function concept is useful both as an economic and an engineering tool. By considering input prices the economist finds it a simple matter to choose between efficient processes to find the most economical one; meanwhile the

engineer is busy working with each process to make it more efficient, that is, to make technological progress. It is the task of the firm's managers, finally, to see to it that the firm has chosen the proper process from an economic point of view, and is using that process as efficiently as possible from an engineering point of view.

Since schools can be easily characterized as firms, the production-function concept should be helpful in the analysis of their efficiency. The most immediate problem is obtaining a viable product measure, since the educational process is obviously concerned with a much more complicated product than the steel-making process. But assuming that some reasonable starting point is available for a product measure, the approach would seem to be valuable for examining educational organizations as systems.

It would be of potential value to obtain accurately estimated educational production functions. It would then be possible to obtain a maximum-efficiency solution for the marginal product per dollar of each educational input, and since solution values must be equal for each input when the firm is operating on the efficiency frontier, the estimated function could readily be compared to actual school practices. From the magnitudes of the coefficients (multiplied by the proper dollar costs of their factors) one could infer which input ought to be increased relative to the others.*

But such estimated production functions will not be obtainable in the near future, if ever, and it is therefore heroic to use such attainment as the ideal against which to judge current work. Inasmuch as this ideal has tended to divert the attention of researchers from noticing potential policy insights which could be obtained with less sophisticated analysis, such idealism, in itself, may have been harmful.**

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*Farrell [1].

**Thus, Brandl [2] in commenting upon Bowles' [3] early discussion of the educational production function, concludes that the paper "leaves little room for hope that estimations of educational production functions from survey data can be very useful for policy purposes in the forseeable future" (p. 1). Brandl's pessimism is based almost entirely upon the failure of such analysis to achieve the marginal product ratios discussed above, apparently forgetting that such analysis may have other important,

Most of the problems which we would encounter if we attempted to fit true educational production functions to survey data can probably be reduced to two general categories: our inability to specify the form of the production function *a priori*, and the many problems arising out of data limitations.

THE PRODUCTION FUNCTION FORM

For a manufacturing concern, production function estimation requires a knowledge of the different factors important in producing the product and the chemical or physical interactions between the inputs. For example, steel manufacturers know what combinations of iron ore, oxygen, and various skilled labors, etc., are needed to produce a ton of a specified grade of steel using the Bessemer process, and chemical engineers know what physical and chemical reactions there are between the inputs for the raw materials to be changed into the final product. For education there is no well-developed theory of instruction to show how the process of learning takes place. While researchers such as Gagne [4] and Vernon [5] have made a good beginning toward understanding the fundamentals of the process by which we learn, and these may eventually be applicable to a resource variation model, such application is in the future.

Indeed, were we to try to list the essentials for specifying an educational production function, we would find that we do not know what the relevant outputs are, and probably will not until we ascertain the meaningful dimensions of learning that society desires. Nor do we know the proper dimensions of the vector of educational inputs. Is a masters degree in education a relevant teacher input? A year of experience? A sense of humor? Without such knowledge, we can hardly expect to know

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if less exalted, insights to contribute aside from attaining such lofty goals. In the paper to which Brandl refers, as well as in later work, Bowles participates in this pessimism, stating that it would be "adventuresome" to take his results seriously. Bowles makes this statement, I think, because he sets *production function estimation* as his goal. From that standpoint his pessimism is correct. But Bowles' own craftsmanlike studies of Negro twelfth-grade students provide considerable useful information concerning the workings of American education.

the mathematical specification of the mathematical form that the production function would take: would the effects of inputs be additive, or multiplicative, or sometimes one and sometimes the other?

II. DATA LIMITATIONS

With currently available data, it would not be possible to construct educational production functions even if good theoretical specifications were available. Some of the most important limitations of the data sets which have so far been available to us are listed below. This list is undoubtedly not exhaustive.

TOO FEW TECHNOLOGIES

The lack of enough technologies is possibly the most serious data limitation that we have, the seriousness of which does not seem to have been generally recognized. A production function includes optimum combinations of inputs for *all* distinguishable production techniques, not merely one or two. Up to the very recent past, American education, despite its widely decentralized decisionmaking structure, has utilized essentially one educational technology--group instruction in the self-contained classroom--and none other. What variations we are able to observe using historical data are variations within this single technology, and while observations of successful variations are useful and insightful, the range of experience is nevertheless much too narrow for us to fit educational production functions. This fact makes most of the discussion about developing educational production functions somewhat beside the point.

ERRONEOUS VARIABLES

Only crude variables, many of them inadequate proxies for things researchers would have preferred to measure, have been available. In the area of performance measures, the problem has been that simply not enough dimensions have been measured, as was discussed above. A listing of important problems concerning variables for educational inputs would include the following points:

1. Teaching characteristics have been described by standard items in personnel folders--degree level, years of experience, salary, and the like. An adequate theory of instruction would require data concerning types of instructional techniques, time spent on them, order of presentation, etc. But even without such exact analysis, the

teaching variables leave much to be desired. For example, data on basic teaching techniques would be useful. Information is also needed on the teacher's college major, grade point average, emotional stability, and intelligence.*

2. In many instances a good variable has not been available for class size. Pupil-teacher ratio has often been the proxy used. Because staffing patterns vary, pupil-teacher ratios can be misleading as an indication of class size.

3. There have been virtually no variables available concerning teaching techniques used inside the class; all too often even such simple distinctions as group versus individual instruction cannot be made.

4. Cognitive test socres are not cardinal measures and are not very meaningful for "nonaverage" children.**

5. Socioeconomic status (SES) variables have often been suspect, especially when used for small children. SES variables in the Equal Opportunity Survey were biased, perhaps considerably, beaause of a poor response rate.

6. There have been no good measures of management quality or of school physical inputs. The variables that have been available in these two areas have often been dollar aggregates (expenditure in, or value of, plant and equipment, etc.) and the researcher has no way of knowing for certain how the dollars were spent.

7. Even variables for race have not been as good as many seem to think, since they normally do not give patterns of racial mixture in the classroom.

NON-LONGITUDINAL DATA

A somewhat special problem exists because most educational data sets pertain only to one point in time. This is a serious drawback in determining correct model specifications, expecially when there is considerable pupil mobility. Such observations are only useful if the researcher is assured that few or no pupils have moved into the school during the assumed treatment period, which is in most instances the time from the first grade level to the grade level being studied. In working with cross-sectional data, this problem is dealt with by selecting only observations of children

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*The Equal Opportunity Survey data [6] and Hanushek's California data [7] have included a crude (Hanushek's somewhat less so) measure of teacher verbal ability which has proved to be an informative variable.

**A thorough discussion of this point can be found in Coleman and Karweit [8].

present in the school during the entire treatment period. But this method does not eliminate the problem if the pupils who move out of the school are not randomly distributed, since non-random distribution would bias the results. For example, if the highest and lowest socio-economic groups are the ones that do most of the moving, the analysis for those groups may be meaningless. It is even possible that some more systematic bias is introduced. For example, perhaps the best students from both the highest and lowest SES groupings move often (where "best" means "students whom the school was most effectively educating" and vice versa for worst).*

The phenomenon is due partly, I think, to the fact that the students being educated most poorly tend to move more. Moving *per se* is disruptive to education, and children who move often can be expected to perform poorly, all other things being equal, although it should be noted that many excellent students with fine records are children of professional people (such as corporation managers, college professors, service officers, and the like) whose life styles require them to move often. We may be overstating school effects by using only the scores of children who were present for the entire treatment period.

LACK OF INDEPENDENT VARIANCE BETWEEN VARIABLES

Another serious problem enountered when using historical data concerns the high correlation between most meaningful school and socioeconomic background variables. The school which employs better-prepared teachers with superior verbal facility also has more highly motivated children from education-minded families. This difficulty will probably require carefully devised experiments, along with an adequate theory of learning, to overcome. It is especially serious

*This danger has been little investigated. One of the first things I noticed when studying the 1960 New York data [9] on 89 schools, both elementary and secondary, throughout the New York State public school system, was that the levels of achievement for pupils present throughout the three years of the study, 1958, 1959, and 1960, were considerably higher than score levels for pupils present only one or two years.

when the researcher does not have socioeconomic data for individual children.

In least-squares multiple regression analysis [10], collinearity affects two variables by increasing the standard errors of the regression coefficients for the collinear variables when the variables are in the estimating equation together. The coefficient values themselves are not biased. But the result of the estimation procedure is no trick; it is a completely "honest" response to the data. In effect, the estimator (i.e., the statistical estimation technique) says that with this result, "You are confusing me by giving me two or more variables which can explain the same thing and I have no way to decide between them. Please provide more data which gives me some clue as to which variable is doing the causing." The investigator may be able to provide more data by introducing extraneous information, or by stratifying, or by providing more carefully for simultaneous relationships. But if, in the presence of considerable collinearity, the equation gives estimates for variables which are much larger than the standard errors, it is safe to say that they can be taken seriously. Many of our school variables have been quite significant even in the presence of great collinearity both with socioeconomic variables and other school variables.

INABILITY TO PLACE SCHOOLS ON THE EFFICIENCY FRONTIER

As we have already seen, a production function is a maximum concept. If we wish to estimate empirically the production functions for the efficiency frontier, we need to know the relevant factor inputs. First, since there is no well developed theory of learning, we do not even know what proper factor inputs making up the efficiency space may be. Lacking this, there is no way to know where the efficiency frontier is because we don't know for certain which schools are on it. Second, only a very limited number of technologies have been used in describing production functions.

But assuming that the variables we include in our educational model are at least crudely relevant, the difficulty remains that statistical techniques which are normally used in econometric work do

not reproduce optimal technologies; instead they produce some kind of average--the average in this case being that of the median firm or school. As pointed out by Aigner and Chu [11] (required reading on this point), traditional statistical techniques, such as t statistics and the like, are of little use in attempting to estimate the efficiency frontier because of problems in statistics stemming from the researchers' interest in some attribute of a population other than a measure of central tendency. Consider, for example, the problem of inferring a population maximum from a sample maximum. What is needed, at the least, is an estimator in which the disturbance term is restricted to one sign (negative in this case).

Could we assume that the average function obtained with multiple regression analysis were related to that for efficient points in some consistent manner, then this problem would be less serious. For example, if we had fit functions which represented the average efficiency for *all* factor inputs, then the marginal rates of substitution between inputs would be the same, since the relation between average and optimal use of each factor is the same constant fraction. But the existence of this much symmetry is by no means assured. As Aigner and Chu [11, p. 830] state, "it would be infeasible to assume that a firm which possesses average technology with respect to capital always has an average technology with respect to labor . . . (and this is) . . . even less likely when factors are treated in more definitive categories."*

SIMULTANEITY

Probably no problem area in educational production function analysis points up the difference between obtaining true production functions

*Of course, econometricians are not at a loss to treat maximization problems of this kind. The problem can easily be couched in terms of linear or quadratic programming. Aigner and Chu [11] compared linear programming and multiple regression techniques with some industry data and found that the capital coefficient for the linear programming equation was much different from those obtained by regression techniques. While working with the 1960 New York public school survey data [9, 12], I found teacher-pupil ratio to be highly important when linear-programming was used but unimportant when the average function was fitted. I think that more work needs to be done with linear programming techniques using school data.

and obtaining general policy insights more than the existence of simultaneous relationships. Obviously, no complex social phenomenon such as the process of learning has causative patterns which are completely unidirectional. There are many interactions and feedbacks. School factors may affect pupil achievement, but pupil performance itself can affect both school inputs (higher performing pupils increase teacher morale, for example) and the home environment (higher performing students increase their own and their parents' motivation towards learning), as Levin [13] has effectively shown. And, of course, the presence of good (and poor) schools is itself normally caught up in a circular pattern of causation. People who are highly motivated toward quality education for their children move to communities where there are good schools; the presence of children from such families helps ensure the school's success, which causes more highly motivated people to move into the community; such people have enough wealth to provide talented school managers who provide high quality service, and so forth. This circle becomes a vicious circle when it works in reverse.

The researcher who has as his goal the discovery of true school technology could not safely neglect to account for the elements of simultaneity. For example, the results of two instruction techniques may vary: one may teach more words in the short run but do so at the expense of lowering pupil motivation later. One may affect student attitudes less but parent attitudes more. Thus, it is probably true that multiple-stage estimating techniques will be necessary once theory and data become adequate for a serious attempt at estimating production functions. For obtaining important policy insights single stage methods should probably be adequate, especially since there are reasons to believe that the impact of school variables are conservatively stated in the outcomes, a point to be discussed further after the next section.

AGGREGATION OF DATA

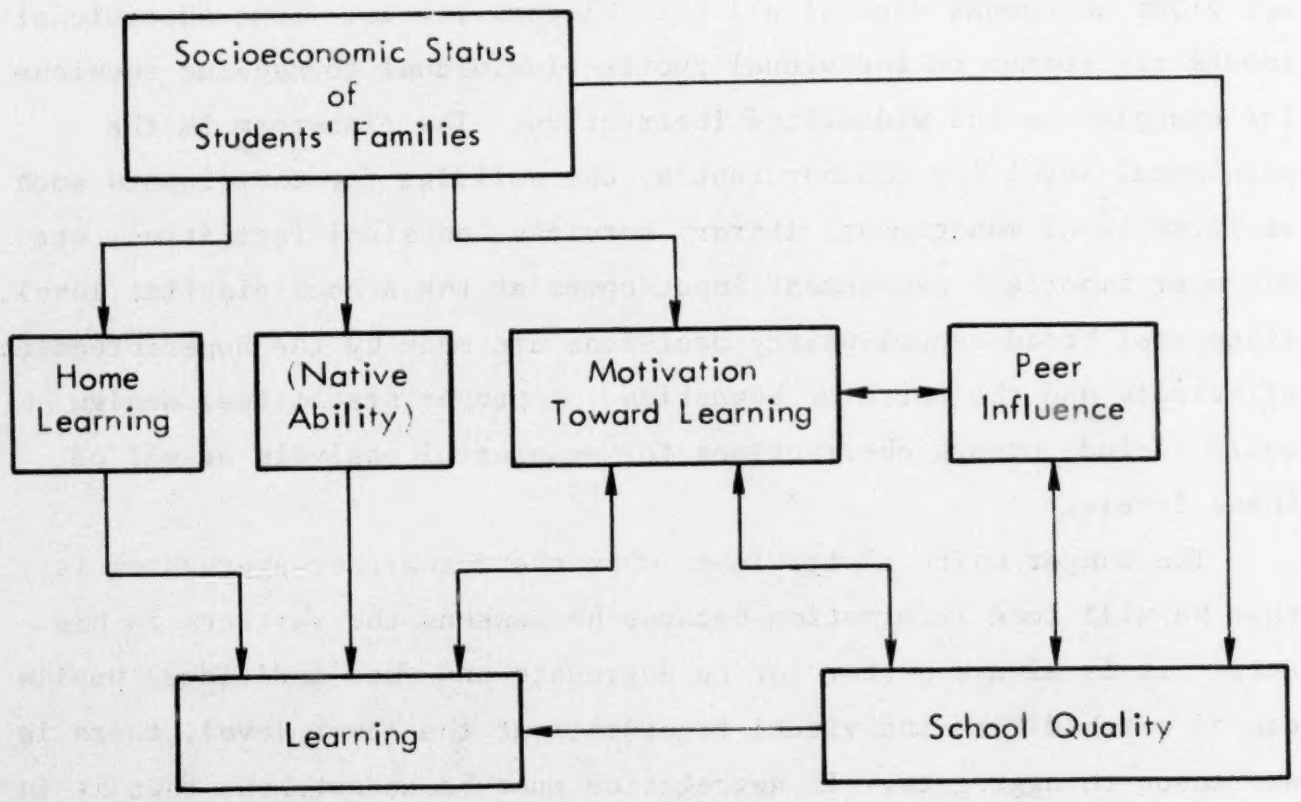
Another troublesome problem exists because educational inputs enter the production process at differing levels, and no existing data

set gives us enough data at all the relevant levels. Some educational inputs are common to individual pupils--individual counseling sessions, for example--or individualized instruction. The classroom is the meaningful level for teacher inputs, the building for many inputs such as first-level management, library services, physical facilities, etc. The most important management input comes at the school district level, since most broad school-policy decisions are made by the Superintendent of Schools and the Board of Education. A proper statistical design would include enough observations for meaningful analysis at all of these levels.

The danger which always looms when the researcher aggregates is that he will lose information because he lessens the variance in his data. It is always better not to aggregate and when individual pupils can be matched with individual treatments at the lower level, there is no reason to aggregate. If aggregation must be undertaken, then it is mandatory that the researcher sees to it that there is no great variation between treatments at the lower level. For example, I defended the aggregation of schools into school districts in the 1960 New York Study [9] on the basis that the districts included in the analysis were small and that the variance in pupil socioeconomic backgrounds was small between buildings. Nevertheless, aggregation was no doubt harmful to the analysis.

BIAS BETWEEN SCHOOL AND SOCIOECONOMIC VARIABLES IN SINGLE--STAGE MULTIPLE REGRESSION ANALYSIS

Consider the following, somewhat simplified model of the educational process. Arrows indicate the direction of causation.



A proper statistical design would correctly show the influence of the four sets of variables (three, if Jensen's ideas [14] of the relationship of socioeconomic status and ability are incorrect) which directly affect student performance, but would admit the influence of the socioeconomic characteristics affecting these things only indirectly. As Levin has pointed out [13], two-stage least-squares techniques can deal with socioeconomic variables at one remove in this manner, as well as dealing with simultaneity problems represented by the double-headed arrows in the diagram.

Now assume the existence of a data set which has no variables for home learning, pupil native ability, and motivation to learn, but has instead an overall socioeconomic status measure, such as father's education, used as a proxy for these things. This would be acceptable except for the fact that, in the aggregate, socioeconomic status of families in the school district is an important cause of school quality. The resultant estimating model improperly credits socioeconomic status with aspects of school quality that are related to it. Stated another way, our interest as researchers is properly upon the effect characteristics of quality schooling have upon pupil performance, and not upon the way the schools came to have such characteristics.

Since school quality can itself affect motivation, there is also causation running in the opposite direction which would tend to understate socioeconomic effects. The net direction of bias as to the interpretation of the importance of school versus socioeconomic variables, then, depends upon whether the effect of school quality upon pupil motivation is stronger or weaker than is the effect of the aggregate socioeconomic character of the families in the school district upon school quality. Assuredly the latter effect is the stronger (most effects probably come from reasons of socioeconomic status, not school) and therefore the overall effect of school variables in such a model is understated.

One way to circumvent the problem in part is by stratifying the children according to socioeconomic background, since the effect of socioeconomic status upon school quality is an aggregate effect and the effect of home learning, ability, and that part of motivation not coming from peer groups is an effect coming from the families of the students. The contribution that stratification has to make has been widely overlooked by researchers, perhaps because of Bowles' early (1968) stand (which I consider incorrect) against the usefulness of stratification [3].

III. MULTIVARIATE ANALYSIS AS A USEFUL TOOL

Few would dispute the fact that the list of difficulties given in the previous section precludes any successful attempt to fit educational production functions in the near future. But it is the contention of this paper that multivariate analysis can yield important insights into American educational problems at the present time and that it can do so in the presence of all or most of the difficulties outlined above.

I think it is safe to say that research and analysis of American educational practices has been hampered in the past by not having an overall framework that could be used to relate the many individual studies of teaching techniques, teacher characteristics, etc., performed by individual researchers, most of them in the universities. Many of these used the device of a control group and an experimental group. Most such studies have been, and still are, unrelated to each other. What are the reasons for this? First, output (or criterion) measures have varied widely with no common denominator by which to relate them. Second, there has been little assurance that different sets of control and experimental group experiments were comparable with respect to variables not in the experiment, including socioeconomic characteristics of the children, school differences, and even the amount of the researcher's enthusiasm going into the experiments.

The multivariate approach discussed in this paper sacrifices some experimental precision vis-a-vis the experimental-group, control-group methodology (in part made up by the use of large sample sizes). But it comes to grips with these difficulties by means of the following techniques:

1. Using comparable measures of output across large experiments;
2. Accounting systematically for differences in socioeconomic background; and
3. Treating the school as a complete system in which different experiments can be related to each other.

All three of the techniques just listed can be fulfilled in an analysis that may fall far short of specifying educational production functions *in toto*. But these three techniques, especially the first two, are precisely what differentiates the multivariate work being

discussed in this paper from other work. Comparability will never be obtained without using the same, or at least highly similar, measures of output across the entire experiment. Nor will it be forthcoming without some assurance that socioeconomic effects are reasonably well accounted for.*

What kinds of results might we expect from such work? At least three can be listed. First, the findings provide a useful perspective for organizing educational research. Second, this approach has given us much valuable information toward a meaningful *description* of American education. Such a broad description of schools viewed as systems has yielded a number of insightful hypotheses discussed in some detail in this paper. Finally, this approach gives us a convenient framework within which to work for the planning of future research.

USES OF AVAILABLE INFORMATION

Although it would be of great significance to decisionmakers who have responsibility in broad school-policy areas to have true production functions, there is nevertheless much that can be learned without such knowledge. And we can readily tell which inputs are important to policymakers merely by observing the way in which they allocate their resources. Policymakers allocate resources for more teacher and management experience along narrowly prescribed lines, and for smaller classes and certain types of facilities. These inputs become the ingredients of the policy production function and a model so formed is important indeed, accounting for an expenditure totaling almost $40 billion annually in the nation's elementary and secondary public schools [15].

It is true that we do not know *a priori* relationships between pupil performance and such policy variables as teacher experience, class size, and the like. But experimentation with linear and log-linear models can be expected to give us considerable insight into the important relationships, even in the presence of the collinearity problems already mentioned. Qualified researchers, after they experiment with their data, can usually get an accurate indication of what many of the important interactions are.

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*Differences in native ability would have to be controlled also, assuming that they exist and are large.

In product measurement at the elementary level I believe that scores of reliable tests of basic skills capture much of what society wishes children to learn. This can be verified by simple introspection (by those who have attended public elementary schools) and by noticing the importance that educational decisionmakers place upon the scores of these tests.*

At the high school level much more of the educational product goes unmeasured even with such tests; but even here reliable achievement-test batteries are good enough to draw rough policy conclusions. Knowing something meaningful about success in the area of cognitive scores is far superior to knowing nothing at all; and this knowledge should allow us to make some general inferences that will be most helpful in pointing general policy directions.**

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*In the early years of the Federal Title I Program of the Elementary and Secondary Education Act of 1965, many investigators thought that standardized tests could not be used to test minority children from disadvantaged homes because they were not "culture fair." But, although there may be some cultural bias to the popular tests, the fact is now obvious that with good instruction the most deprived minority (as well as majority) children can advance very quickly in basic reading and arithmetic skills and that the tests are sensitive to these increases. And even at the high school level, broad achievement test batteries give an important clue to quality education. Indeed, a strong case can be made to the effect that this is true *even if* the tests have questions concerning subject matter not covered in the high school. Many educators argue that an "educated person" is one who has the curiosity and motivation to learn on his own. A general battery will favor a high school that fosters creative curiosity towards learning.

**It is true, however, that after a few years the usefulness of cognitive scores to researchers may diminish: first, because apparent emphasis on such test scores runs the real danger that teachers will start teaching directly to the tests at the expense of other worthwhile activities; and second, further advances will depend critically on whether other dimensions of educational output can be meaningfully measured with testing instruments. Much of the task of constructing such instruments still lies before us.

Some writers see nothing wrong with teaching to the tests if the tests themselves are sophisticated. I suppose this might be true, but I am also painfully aware of some of the abuses that are fostered by the regents' examinations in New York State and by tests in Great Britain where teachers spend considerable resources going over verbatim questions and answers on past tests, a practice that many feel is harmful. It is to be noted that using general batteries of tests gives rise to much less possibility of "teaching to the tests" than is true with tests covering specific and narrowly defined content areas.

The fact that there has been only one instructional technology to study in the past does not invalidate the work of multivariate analysis to the policymaker. Knowing which types of inputs seem associated with success within the present technology is important for suggesting reallocation and for suggesting directions in which we can move in any new technology. For example, analysis already conducted leads us to the *tentative* hypothesis that relying on teacher experience and formal education as a way of improving educational quality is inefficient; it would be much better to recruit teachers who are intelligent, and to engage in more planning and on-the-job teacher training. This is discussed more thoroughly below. If these hypotheses prove to be validated with further testing, such insights are important indeed.

EDUCATIONAL POLICY APPLICATIONS

When examining broad educational policy questions, the difficulties caused by poor variables are much less serious than would at first appear. Pupil-teacher ratio may have an importance of its own for policy purposes, but other variables are more useful in our studies. In any case, even if the variable of class size is desired, this can be determined, since staffing patterns in American education do not vary greatly, even from one state to another.* While the grade equivalent is not a cardinal unit, strictly speaking, yet it is a unit that is readily understood by, and important to, many educational policymakers. The socioeconomic variables in many of our studies were gathered quite carefully, and their high correlation with pupil performance gives heuristic support to the notion that they are fairly adequate. Dollar aggregates may also be meaningful in giving clues to the operation of schools, again because school practices within the single technology which has been used do not vary greatly. Expenditure per pupil is of *direct* interest to policymakers, and its relation to performance can give the researcher valuable information about efficiency. Indeed, expenditure per pupil is important if only because many economists have

*At least so it would seem from my observations of schools in New York, Indiana, and California. Since 1966 this has been less true for some schools with many low socioeconomic students, since many Federal Title I programs have introduced staffing patterns that are at considerable variance to the traditionally self-contained classroom.

in the past used it as an index of school quality. Finally, the variables which determine salary in most American school districts are experience and number of degrees. For testing a model of educational remuneration, these are precisely the variables we would wish to have.

It is no doubt true that for meaningful description of relationships in American education, cross-section analysis can be quite productive. However, if the researcher wishes to pin down causation more precisely, there will be no recourse but to use longitudinal data. This is true whether the researcher is interested in fitting models to test general policy or whether he is attempting to build an educational production function. To be sure, failure to have longitudinal data is much more debilitating for the latter. Indeed, I doubt whether we can approach the estimation of educational production functions using only cross-sectional data. Sound evaluation of different instructional technologies will require careful experiments which follow the pupils through time.

But for policy insights much can be done with cross-sectional data if supplemented with other knowledge about the sample being used and about the technique. The most helpful supplementary data required is the rate of pupil mobility. If pupil mobility is not excessive, and also if it is reasonably similar across the sample, then cross-section results are reliable enough for most general questions of policy. Further, cross-section results can be related to longitudinal results whenever a data set with longitudinal data is available. To my knowledge, there have been two such data sets, Hanushek's [7] and my 1960 New York sample [9]. I found in the New York data that results for Grade 6 pupils were extremely similar, whether using Grade 6 scores only (duplicating a straight-forward cross-section approach), or subtracting Grade 4 scores from Grade 6 scores, or using Grade 4 scores as an explanatory variable in the equation explaining Grade 6 scores. All these approaches give very similar results. When the cross-section results for sixth grade pupils who had attended fourth, fifth, and sixth grades at the school were compared to those for *all* pupils, the results for the latter were found to be similar to those of the former, with the result that both the coefficients of net regression and values of t were about 25 percent to 30 percent smaller.

Although Hanushek did not report on this aspect of his study in print, he has indicated to me in conversation that he found enough differences in the results done in the two separate ways to counsel caution.*

*For the two approaches to yield similar results would of course require the year-to-year gain in achievement performance to be a log-linear function of beginning score. This is a reasonable assumption that often fails in practice. For example, in my study, presently in progress, of California compensatory education projects, I found that gain and beginning level of score were *negatively* correlated.

IV. AMERICAN SCHOOLS AS REFLECTED IN MULTIVARIATE STUDIES

Assuming that the multivariate approach is relevant to educational policy even in its present state, it is now necessary to see what we can learn from the studies themselves. In this section I shall try to summarize what I consider to be the more important findings contained in some fifteen studies of American schools listed in Table 1. In this short discussion I cannot attempt to make an exhaustive survey, and I choose not to discuss the findings in some British studies, as beyond the scope of this paper. Further, some of the conclusions are based upon work of mine which is as yet unpublished; I will attempt to substantiate these points in the footnotes. After presenting the material by topic and then summarizing it, I shall sketch the picture of American education that I see represented. The vision is, to be sure, not crystal clear, and the hypothetical construct given is therefore highly tentative.

THE IMPORTANCE OF ENVIRONMENT TO EDUCATIONAL SUCCESS

The most pervasive impression to be gained from these studies is that student performance is always related to socioeconomic status. The general finding of the Coleman report [6] that our environment is a powerful educational source is certainly not contradicted. Table 1 lists the relative strength of the strongest socioeconomic and school variables in most of the studies surveyed. All of the studies that used socioeconomic variables found them highly related to pupil performance, and most found them much more related than the most important school inputs.* On the other hand, school characteristics were often strongly related to pupil performance as well; school effects are not so unimportant as many have thought after reading the Coleman report [8].**

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*As an example, in the 1965 New York Study [16], the effect of a change of one grade level in Mothers' education, out of a total of six possible grade levels, averaged out to a difference of between four and five academic months of performance for children who were themselves from the same educational background.

**The most important reason for this is that the statistical design in the Coleman report itself did not give equal consideration to school and environment factors. See Bowles and Levin [17], or Kain and Hanushek [18].

Table 1

VALUES OF t FOR THE MOST SIGNIFICANT (STATISTICALLY) SOCIOECONOMIC AND SCHOOL VARIABLES

Study[a]	Socioeconomic Status Variable	t Statistic	School Variable	t Statistic
Kiesling, 1969	Average occupation level of father	3.5	Per-pupil expenditure on principals and supervisors	3.1
Hanushek, 1968				
Whites	Goods index	10.6	Teacher experience	3.0
Blacks	" "	7.9	" "	2.6
Bowles, 1969a	Family has TV, telephone, radio, phonograph	4.5	Class size, science and math	2.1
Bowles, 1969b	Parents' educational level	4.4	Teacher verbal ability	7.1
Kiesling, 1970	Mother's educational level	7.4	Teacher certification	4.4

NOTE: Studies selected had models which included both SES and school effects for the same children. Only studies using single-stage methods are included. Although the number of observations in these studies varied, we can say that, as a general rule, a value in excess of 2.0 is significant at the 5% level, and a value in excess of 2.6 is significant at the 1% level.

[a]An annotated list of multivariate studies from which these studies were selected is shown below (p. 42).

In judging the effect of socioeconomic factors in educational performance, it is well to remember that for various reasons homes of high socioeconomic status provide more educable children to the schools than do other homes.* A strong case can be made that it is the school that should get the credit when the potential inherent in these children is realized, not the home environment.

There is some evidence in these studies, secondly, that American schools do best for middle-class children. In both of Hanushek's studies [7, 18] the racial minority children, who also had low socioeconomic status on the average, were related to school effects much less than were the majority children. A similar finding came from my first New York study [9]. Katzman [19] found that it was "easier to improve" the performance of pupils from good than from poor backgrounds.**

In the two New York studies it was possible to note the relative impact of schools on children from the highest socioeconomic backgrounds. In the 1960 study [9] the children of highest socioeconomic

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*This is true whether or not Jensen's thesis [14] that intelligence is, on the average, related to social class is correct. Motivational differences would be great even if intelligential differences were nonexistent.

**It should be noted, however, that Bowles [17] and Hanushek [18] found a number of school effects related to the performance of twelfth-grade black students. Such effects included educational innovations, percent of teachers with graduate training, expenditures on non-teaching inputs, teacher verbal score and teacher experience. Bowles did not compare his findings to non-black students, but Hanushek, who did, found teacher verbal score and experience somewhat more related to white student performance.

In interpreting these findings it must be kept in mind that it is not proper in general to equate Negro students with low socioeconomic students. Also, since both of these authors used achievement of twelfth-grade students as the output measure, all of the students who dropped out of high school are not represented in the equations. The direction of the resultant bias is obvious and, from our knowledge of the dropout rates of black children, its size would be large.

It is perhaps proper to note here that my work with H. James Brown using some unpublished results obtained from fitting multivariate models to the average scores of all-black Project Talent high schools indicates that there is little correspondence between school variables and pupil achievement performance. The single exception was teacher starting salary for ninth-grade children, and even then the variable was significant only at the 10% level.

status were little affected by school variables: they tended to do well no matter what the characteristics of their school. In the 1965 study [16], however, this tendency was much less pronounced.*

A direct way to assess school effects on pupils of low socioeconomic backgrounds, sometimes overlooked, is simply to examine the strength of the socioeconomic variables in each study. As an example, in the 1965 New York study data [16], the net effect of an additional level of mother's education was to increase predicted average achievement performance more than 0.7 years in Grade 5. While the sheer size of this effect is eloquent in itself, the fact that the magnitude of the effects of socioeconomic variables normally do not decrease as grade level increases is even more telling.

SCHOOL CHARACTERISTICS AND PUPIL PERFORMANCE

Findings concerning the strength of environmental factors in the educational process are useful, but schools remain our central concern. A great many school characteristics were considered in these studies; some, such as teacher experience and pupil/teacher ratio, were included in most of them. The most important of these are gathered together in

*The following table compares the t statistics for five school variables for pupils from homes where the father was a college graduate with pupils from homes where the father had between 8 and 12 years of education.

School Variable	Father's Education	
	College Graduate	8-12 Years[a]
Teacher experience	1.69	0.27
Teacher salary, Step 10 master's degree + 30 credit hours[b]	0.53	-0.45
Pupil-teacher ratio	0.12	0.07
Administrative expenditure per pupil	1.12	3.85
College hours in subject taught	2.07	3.64

[a]Averaged for three education levels: grade-school graduate, same high school, high-school graduate. The variation in the t statistics for the three groups was extremely small.

[b]Tenth step of the New York data [16] salary schedule for teachers with a master's degree.

Table 2. The school variables can perhaps best be discussed by division into three groupings: those having to do with teachers, school administration, and facilities.

Teacher Variables

As it would be reasonable to expect, the greatest number of variables represented in the studies were related to teachers. Of these, the variables of most interest to researchers who would broadly test American educational policy are those which shape salary. The almost universal convention in American education is the single salary schedule, by which all teachers are paid almost exclusively on the basis of years of experience and amount of college training, once starting salary is known. Teachers with the required number of college units, including the requisite number of hours in education courses in their state, are formally "certified" by the state.

It is striking to note that such pay-parameter variables were seldom found to be related to pupil performance in these multivariate studies. Variables having to do with college training were virtually never important, with the single exception of number of graduate hours being related to black twelfth-grade student performance in one of Bowles' studies [17]. Teacher certification, in the sense described above, was never significant either; in the one study in which certification was significant, Kiesling [16], the variable was a measure of number of college hours in the subject being taught. This leaves experience as the only pay-parameter variable related to pupil performance, which it was in about half the studies.

The force of the foregoing result is vitiated somewhat by the fact that teacher salary itself often seems to be related to pupil performance. There is a statistical problem involved when both salary and variables that determine salary are entered into the same explanatory equation. This could perhaps account for some of the null findings for the pay-parameter variables.*

*This comment would be more true when average salary was used as a variable than when some other form of the salary variable was used. For example, in the author's study of the 1960 New York data [9], the

Table 2

RESULTS OF SCHOOL MULTIVARIATE STUDIES

Variable	Expected Sign	Significant Statistically with Expected Sign	Non-Significant Statistically with Expected Sign
A. Variables Often Related to School Performance			
Teacher verbal ability	+	Hanushek, 1968 Bowles, 1969b Levin, 1970 Hanushek, 1970[b]	Hanushek, 1970[a]
Teacher experience	+	Thomas, 1962 Burkhead, 1967 Hanushek, 1968 Katzman, 1968 Levin, 1970 Michelson, 1970[d]	Kiesling, 1969 Michelson, 1970[c] Hanushek, 1970 Kiesling, 1970 Averch-Kiesling, 1971
Teacher salary	+	Thomas, 1962[e] Burkhead, 1967[f] Cohn, 1968[f] Kiesling, 1969[h] Averch-Kiesling, 1971[e]	Bowles, 1969a[e] Kiesling, 1970[g]
Per-pupil expenditure on school district administration	+	Kiesling, 1969 Kiesling, 1970	Burkhead, 1967[i]
Ability grouping ("tracking")	?	Positive: Thomas, 1962 Averch-Kiesling, 1971	Negative: Bowles, 1969a
Average class size	-	Mollenkopf, 1956 Thomas, 1962 Bowles, 1969a Averch-Kiesling, 1971	Cohn, 1968

NOTE: These studies are fully referenced in an annotated list following the body of this paper (see p. 42).

[a] Spanish-surnamed children.

[b] Anglo children.

[c] Michelson, 1970.

[d] White children.

[e] Starting salary.

[f] Average salary.

[g] Salary with 18 years experience, with MA.

[h] Salary at 95th percentile.

[i] Administrative man years per pupil.

[j] This certification variable was unique in that it represented the number of college hours in the subject taught.

[k] College university vs. teacher-training institution.

[l] Positive, toward college/university.

Table 2 Continued

Variable	Expected Sign	Significant Statistically with Expected Sign	Non-Significant Statistically with Expected Sign
B. Variables Often Not Related to Performance			
Teacher certification	+	Kiesling, 1970[j]	Burkhead, 1967 Katzman, 1968 Bowles, 1969b Kiesling, 1969 Averch-Kiesling, 1971
Pupil-teacher ratio			Burkhead, 1967 Katzman, 1968 Kiesling, 1969 Kiesling, 1970
Teacher degree level	+		Burkhead, 1967 Katzman, 1968 Kiesling, 1970 Hanushek, 1970
Expenditure on books and supplies per pupil	+	Fox, 1969	Burkhead, 1967 Kiesling, 1969 Levin, 1970 Averch-Kiesling, 1971
Facilities value per pupil	+	Kiesling, 1969	Burkhead, 1967 Cohn, 1969
C. Other Findings of Interest Found in One or Two Studies			
Number of special staff	+	Mollenhopf, 1956	
Percent teacher turnover	-	Katzman, 1967 Averch-Kiesling, 1971	
Educational innovations	+	Bowles, 1969b	
Percent of teachers with graduate training	+	Bowles, 1969b	
Expenditure on non-teaching inputs per pupil	+	Bowles, 1969b	
Science laboratory facilities	+	Bowles, 1969b	
Teacher undergraduate institution[k]		Levin, 1970[l]	
Teacher college hours			Cohn, 1968 Hanushek, 1970
Principal degree level			Kiesling, 1969 Averch-Kiesling, 1971
Percentage of teachers with tenure	+		Michelson, 1970

The school characteristic most often studied for many decades has been average class size. The proxy variable that was available in many of these studies was pupil/teacher ratio.* Most prior work in this area and most of the findings in the studies reported on here show that neither average class size nor pupil/teacher ratio is related to pupil performance. The exceptions were the work based on the Project Talent data [20] and Mollenkopf's study [21]. In some cases (for example, Kiesling [12]), the variable was found to be significant with the wrong sign. An important insight into this finding, taken together with the more frequent positive significance of teacher salary, may have been provided by some work done by Vincent and his associates [22] in which they found that in most school districts managers found it a better bargain to trade increased class size for higher teacher salary.

The teacher variable with the best success ratio in these studies was verbal ability. The variable was collected in Coleman's equal-opportunity data set [6] and also by Hanushek [7] in his California study. In both studies, with the single exception of teachers of Mexican-American children in the California study, teacher verbal ability was significantly related to pupil performance.

A final note concerning teachers: As one would expect, studies which included variables for teacher turnover found them negatively related to pupil performance.

School Administration

There were fewer variables available to measure the quality of school administration. Pay parameters for managers (degree level and

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salary of the 95th percentile of teachers paid was used as the salary variable, while in the study with the 1965 New York data [16] the variable used was salary paid on the tenth step of the school district salary schedule for teachers who had a master's degree.

*As discussed above, since educational practice does not vary widely, the pupil/teacher ratio is probably a fairly good proxy for average class size. A finding by Mollenkopf [21] should give cause for some caution in this, however. Mollenkopf studied both teacher/pupil ratio and average class size and found the latter variable was significantly related to performance, while the former variable was not.

experience) were less related to pupil performance than those for teachers as shown in Table 2C. Otherwise, three studies had findings strongly suggesting the importance of management resources* and one, that of Burkhead [23], returned a null finding concerning the relationship of number of administrators per pupil to pupil performance. This variable was the most consistently important variable in the two studies. In the 1965 New York data set [16], this was equally true, whether schools or school districts were used as the unit of observation. Finally, Bowles' finding [17] that the educational innovations were positively related to twelfth-grade Negro students' performance is probably best interpreted as a management effect.

Facilities

Most of the facilities variables used in these studies have not been very good. Facilities' value and expenditure on books were both used in several studies and in most the variables were not related to performance. Bowles [3], besides his expenditure on non-teaching inputs variable, also had a variable for science laboratory facilities, which he found to be positively related to pupil performance in the Project Talent high schools for black twelfth-grade students.

School Integration

Despite the fact that some of our most important data sets were designed specifically to investigate the question of the effects of racial segregation, we have not learned nearly as much as we would like to know in this matter. Hanushek's equations [18] show a significantly negative relationship to the performance of white students where there are more than 75-percent blacks in their school and a significantly negative relationship to the performance of blacks where there are more than 45-percent blacks in the school. Both effects are small. Bowles, using a different data set (that from the Project

*The studies showing positive relationships were Kiesling [9, 16] and Bowles [3]. The strong statistical significance of the relationship between per-pupil expenditure on central administration and per-pupil performance is most striking.

Talent high schools [3]), found that the percentage of Negro students in the school was negatively related to performance of twelfth-grade blacks. These findings seem to say that, in general, it would be better for both races to keep the percentage of blacks below half, but as both authors point out, we can never be sure that racial effects have been properly separated from school and other socioeconomic effects. Thus, the reason whites do poorer when there are 75-percent or more blacks might be because schools are poor for other reasons, not (directly, anyway) because of the presence of the blacks. These causes also may not be accounted for completely by other school variables in the explanatory equation. Bowles' discussion of this point [3, p. 72] is worth quoting at some length:

> When we add a variable measuring the percentage of the studentbody which is black, . . . [we find that] . . . in two of the three cases there is a significant negative relationship between the level of achievement by our sample of black students and the portion of the studentbody which is black. Given the fact that a measure of the social class and achievement levels of the school (percentage in college preparatory subjects) is not significantly related to black achievement, it is difficult to interpret this result as a peer effect involving the transfer of good learning habits, language models, etc., from the high-achieving whites to the low-achieving blacks. An alternative (untestable) interpretation is that the apparent impact of the proportion of blacks in the school arises from the fact that the social background of black children in integrated schools and those in all-black, or nearly all-black, schools differs in ways which are relevant to learning but which are not captured in our crude social class measures. The results cannot be interpreted as suggesting that school integration will raise black achievement.

In the Coleman report itself [6], the effect that racial composition was shown to have upon performance of blacks was an extremely minute part of the total variance, and there was no effect on whites.

What we have learned by reviewing these several studies, then, is that schools that are mostly black are generally more poorly staffed, and, at the same time, the students do much more poorly. Even blacks from middle-class homes do relatively worse than whites from comparable homes. I would only repeat the conclusions set forth above--that American schools seem to be doing a poor job of educating

all pupils from low socioeconomic backgrounds (with the possible exception of some current Title I projects) and a disproportionate percentage of blacks are in this category.

Number of Tracks

An important policy question in American schools has been the desirability of separating students for instruction into homogeneous groupings according to ability and prior scholastic attainment, often termed "tracking." The study that directly gathered information concerning number of tracks was that concerning the Project Talent high schools [20]. Findings from that data set are most interesting. They showed that number of tracks was strongly related to positive achievement levels for all pupils. On the other hand, Bowles [17] found that the number of tracks was negatively related to the progress of black twelfth graders. On the basis of this data, tracking would seem to be good for majority students and bad for minority students. The same finding could perhaps be interpreted as relating to faster and slower learners.

Expenditure Per Pupil, School Size, and Pupil Performance

While space does not permit adequate discussion of the relationship of school expenditure and school size to pupil performance, we can venture a few words. Expenditure per pupil is of direct interest for two reasons. First, it is a direct proxy variable widely used by policymakers for the amount of dollar effort being expended on schools; second, in the past many economists have used expenditure per pupil or expenditure per capita in public services as an index of quality. In the data at hand, both variables have been somewhat neglected, perhaps because of authors' attempts to deal exclusively with building educational production functions.

Four studies considered per-pupil expenditure [9, 16, 20, 24] and, with one exception, the variable was never highly related to pupil performance when socioeconomic differences were held constant. The exception was large urban school districts in the 1960 New York study [9]. When all the Project Talent high schools are considered [20], the

expenditure variable is strongly related to performance, but when the schools are stratified by type (urban, village, etc.) or region, the relationship disappears. This finding would imply some combination of poor estimating equations and wide variations in efficiency. Part of the explanation could also be that there was no way to deal with existing differences in cost of educational resources.

The question of size has not received nearly the attention it deserves. All four of the studies just mentioned failed to find any positive relationship between size and performance, but of these only the Talent study used school buildings; the others used school districts. Katzman's study of Boston schools [19] showed size highly related to performance. There is also a weakly positive relationship between school size and pupil performance in my New York 1965 study [16].

IMPLICATIONS FOR AMERICAN EDUCATION

What broad picture of American public elementary and secondary education is found in these results? I would argue that the following construct, which is to be considered built from blocks of tentative hypotheses, is suggested by this literature either directly or with the help of easily available supplementary information. The central argument is that traditional educational methodology--meaning the teacher, trained to be an independent professional working in the self-contained classroom--has not been able to cope with technical and societal changes occurring since World War II.

Since much of the following will discuss failures, it is proper to recall at the outset that in many ways American education has succeeded well in the past 25 years from 1946 to 1970. It coped with the problem of undergoing the post-war baby boom and at the same time *increased* the percentage of eligible population entering college from 22 percent to more than 40 percent [25]. Any social institution that can point to such a record is not a failure, no matter what else one may say.

But the juncture has come when it would seem necessary to point out that in some ways American education has faltered. It has failed to

change quickly enough with the times and that failure has been expensive, since change along the lines suggested by the traditional technology to deal with today's problems has been to reduce class size and increase teacher salaries across the board--both very costly.

Let us look at the arguments to support this position:

- *The traditional technology is too exclusively involved with the importance of the classroom teacher.**

Management inputs are highly standardized and very small. School buildings do not vary in design and seldom use non-teacher instructional technologies.

Since the advent of the Federal Title I program, it has become obvious to me that pupil aids can be quite productive of success in the classroom, especially when instruction is tailored to individual learning situations.** The contrasting evidence given above that physical facilities have not been related to pupil performance tends to show that one kind of educational input which has good potential value has been disregarded.

Failure to use physical inputs goes along with the low amount of management inputs, since increased use of physical aids in the teaching process would require more management and teamwork in the preparation of instruction. The few findings in multivariate research that do deal with management tend to show that increasing management inputs would yield payoffs even under the present technology. Management was one of the few school characteristics related to the progress of children of low socioeconomic status. In general, in studying this literature I am under the impression that the role of management has been widely neglected in American education and, indeed, we are abysmally ignorant of the traits of a good school manager.

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*This has been true with many of the multivariate studies as well, especially those based on the Equal Opportunity Survey data.

**Such aids are heavily used in almost all California Title I programs and in virtually all programs where good gains are registered. The successful use of a simple audio-visual teaching machine by the Dorsett organization in Texarkana is also a case in point [26]. Other examples are becoming increasingly available.

- *The teacher utilizing group instruction in the self-contained classroom has not been able to cope well with the demands of atypical students.*

This would seem to be directly suggested by the findings concerning high and low children of socioeconomic status, especially the latter, discussed above. Group instruction obviously implies a reasonably homogeneous classroom. All teachers are painfully aware of the problem of what to do with the very good (bored) and the very poor (lost) students.

The obvious answer to this dilemma from the standpoint of the traditional technology is "tracking." But Bowles' [3] interesting finding concerning the adverse effect of tracking on black students would imply this is no solution for such children either. Tracking also has the well-known danger that a student might be placed in too low a track and be irreparably harmed.

- *One possible solution to dealing with difficulties facing education--reducing class size--does not seem viable.*

Most evidence shows class size unrelated to pupil performance and lowering class size is extremely expensive.

This finding is somewhat puzzling, since lower class size obviously should allow the teacher to give more attention to individuals. I think the finding probably reflects two things. First, within the range of variation of class size taken in most of these studies, between 20 and 30 approximately, a reduction in size still does not allow significantly more individual attention. Second, American teachers are so accustomed to dispensing instruction to the whole group that they do not seize the opportunity to individualize even when it occurs. There are costs involved also, such as writing separate examinations for the bright students who have been given extra work, and so forth.

- *The incentive-reward structure for the school system's only important input--teachers--has been unsuccessful.*

It was shown above how most pay-parameter variables are unrelated to pupil performance. The exception was salary itself. This would suggest that the only important incentive in the system is that given by the attractiveness of a given school district in the first

place. (This is in turn a function of school management.) After the teacher is hired, job performance incentives--at least economic ones--which are related to classroom effectiveness fail to operate forever after.

- *Since the number of college hours completed by teachers is seldom related to performance of their pupils, something seems amiss with their training.*

Since there is evidence in one study that hours in the subject being taught are related to pupil performance, it may be that it is the education course material that is ineffectual.

The fact that, with the exception just noted, no teacher or manager degree level was *ever* related to pupil performance in these studies strongly implicates American schools of education in the educational failures being discussed. It would be only natural for schools of education to perpetuate the mystique of the teacher as a self-sufficient professional whose training has prepared him or her for all contingencies, including going into educational management. In the framework of our traditional educational technology the teacher is viewed as a professional who, like a physician or dentist, requires minimal supervision. This idea requires critical reappraisal. It has in fact not been true for decades (witness the practice of principals monitoring classroom instruction), but the myth remains. Team efforts will not proceed smoothly until this myth is replaced by a more operational one.

More can be said concerning the failure of the training of American educators. Teacher verbal skills appear to be the character trait most related to pupil performance in the educational technology, judging from the studies which have been reviewed.* This finding conflicts with outcomes from some earlier studies [28], and therefore we must proceed cautiously, but let us assume that it is true. This implies that the present system of teacher selection and education is failing in another important respect, since verbal ability of education majors consistently falls below the general college average

*Richard Turner [27] feels that teacher intelligence is highly related to the teacher trait "warmth and spontaneity," which he was most able to pinpoint as being characteristic of successful teachers.

(itself not very high). A number of studies have pointed this out: see especially the report of the Second Commission of Human Resources written by Folger [29], and also the Coleman report [6].

Two further points follow from this. First, average verbal ability of teachers becomes lower as their average age increases, since the best (especially the males) leave the profession according to Folger [29]. Second, technologies which need talented managers could get started only with great difficulty, since regulations in almost all states require managers to be drawn from the ranks of teachers who, of course, have the ability levels just described.*

I would argue that the construct just outlined of American education is that which is most consistent with the findings in the multivariate studies reviewed in this paper. If the construct is also reasonably representative of the real world as well, some obvious directions for public policy are suggested. We need to experiment with new organizational designs incorporating teamwork and various audiovisual aids fast becoming so feasible to use. Much more work needs to be done to develop organizational structures that can effectively and cheaply deliver good individualized instruction if not at all grade levels, at least at some grade levels, and at least for atypical children. Studies should be designed using some of the types of instruments that have already been developed (especially in the case of teachers) to investigate what it is about teacher and manager skills that relates to pupil performance. This will be less difficult to do when studies are designed using the methodology being discussed in this paper to ensure that results of various studies are comparable.

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*This should not be taken to mean that there are not some highly intelligent and talented managers in American schools, however. Many of these are persons who are tapped for administrative roles early in their careers, before they have had occasion to become disillusioned.

V. SOME FURTHER USES OF MULTIVARIATE ANALYSIS ACCOUNTABILITY AND NEW DIRECTIONS FOR RESEARCH

To use multivariate analysis would require a proper information collection system within a given school system--a state system, for example--to provide helpful state research and guidance to local school administrators. Once established, the data collection cost would not be large. With slightly more data it would probably be possible to establish a viable system of accountability.

The key to doing these things is to render different schools and school districts comparable through controlling for socioeconomic differences. Again the *sine qua non* is good data concerning the child's socioeconomic environment. Using this information as one variable in an explanatory model of school quality (measured initially by cognitive test batteries and later by tests designed to measure the attainment of other goals), useful comparisons can be made by state personnel which should allow them to spot districts and schools doing exceptionally well or poorly. Subsequent investigation may yield important information about their performance. Such further investigation could be in-depth study through visits, or by means of multivariate techniques, or both. For example, regression equations can be fitted for state school districts in which pupil achievement is made a function of pupil socioeconomic status and school current expenditure per pupil (deflated to account for differences in educational costs). Next, the computed coefficients of net regression are fitted to the socioeconomic status and expenditure values for individual districts. If the predicted score is much lower than the actual score, the district is exceptionally efficient and vice-versa. It would then be useful to find out why.

Further work with other school variables in multivariate analysis may show that some are often associated with success. In due time, state personnel should be able to develop a manual of successful practices that could be most helpful in their efforts to give meaningful guidance to individual school districts. Perhaps, also, the patterns of success and failure so obtained might suggest changes in state laws and regulations with respect to education.

DEVELOPING BETTER RESEARCH METHODOLOGY

The kind of analysis discussed in this paper provides a framework within which a number of important areas can be meaningfully studied. From the weaknesses of past studies, it can be seen that further work in the following areas is readily suggested as desirable. Other areas for future research will undoubtedly occur to the reader.

Measures of Performance

Use of this kind of analysis will force us to develop other objective measures of performance besides cognitive test scores if we are to come to grips with measuring the result that our schools and communities wish to accomplish. The proper procedure is to establish what it is that the community (through the school board, working closely with the superintendent) wishes, and to develop instruments for measuring each objective. At the outset even relatively crude ones will do. At this stage this analysis ties in closely with performance budgeting, which is concerned with identifying goals, constructing alternative ways of achieving them, and carefully calculating the efficiency of each method. Performance budgeting will allow the costs of each alternative to be exactly stated. Multivariate analysis will provide the evaluation of each as they are tried. *Performance budgeting and good multivariate "production function" designs fit together hand and glove.*

Pupil Mobility

With proper data collection, much can be learned concerning the effects of pupil mobility upon their educational progress which would undoubtedly suggest techniques for dealing with such children.

School Size

The hypothesis suggested by the work done with schools thus far is that school and school district size is either unrelated or negatively related to school performance. Much good analysis is possible in this

respect. Important would be data concerning the organizational structure in school buildings and school districts. If school districts become unwieldy beyond a certain size, the policy implications are obvious.

Geographical Differences

Core city schools in this country always do more poorly than others, even when we account for socioeconomic differences (although perhaps in this instance, we are not accounting for such differences enough, since they are usually quite large). Why is this? What can be done about it? This issue is closely tied to the size question just discussed.

Relation of Longitudinal Outcomes to Cross-Section Outcomes

Information relating results of cross-section studies to longitudinal ones would be of great use to the researcher. Despite the problems, are cross-sectional findings a good proxy for the longitudinal ones we would prefer? As already seen, results in my 1960 New York study [9] suggest they are, but those in Hanushek's California study [7] suggest they are not. More work is needed.

Personnel Characteristics

Some educational psychologists, notably Turner [28] and Ryans [30], have developed instruments for testing teacher's task-solving skills relative to various personality traits. This kind of information, plus data gained from experiments concerning the use of alternative instructional techniques, could be quite instructive. It might provide the beginning clues we need for constructing "true" educational production functions. Similar instruments could be designed for management personnel also.

Intelligence Characteristics

With proper instruments, much work could be done concerning pupil ability in various learning dimensions which could be potentially very helpful in finding an educational program at which every child could be successful.

MULTIVARIATE ANALYSIS AND THE FUTURE OF EDUCATIONAL RESEARCH

It is important that some careful thinking be devoted to the question of the proper levels for conducting educational research and development. Virtually all past work in this area has suffered from a lack of central direction (although I do not mean to say that all useful educational research needs central direction) and from the lack of a useful base for comparison. The multivariate approach discussed in this paper can provide the latter. How are we to achieve the former?

In the past, what central direction there was came from the universities. Theories became popular often because of the influence of a highly regarded teacher, and many researchers, most of them former students of this professor, would develop their research work around the work of their teacher and a certain integration of research was achieved. But beyond this, work in the universities has not focused directly on questions of interest to the policymaker. Most work used a success criterion designed by the individual researcher that was only remotely comparable to criteria used by other researchers. And it must be added, unfortunately, that under the pressure to publish in the universities, many studies lacked the scope and depth necessary for proper control of all factors besides those being studied.

The mechanism for the adoption of new discoveries by the academic researchers is supposed to work through the classroom. Teachers are to learn about new methods when they themselves are students in the school of education. Having learned about new techniques, they can and will put them into practice, unsupervised, in their own classrooms. Indeed, so the theory goes, supervision can be positively harmful, since the supervisor probably was a student in the school of education one or two decades before, and his information may be obsolete.

It immediately becomes obvious to the researcher how the many requirements upon teachers to do advanced college work fit into this scheme: If the teacher is away from the fountainhead of educational innovation too long, she will become outdated by change. She must be required to come back and catch up on the latest. But what has our research told us about this system? In no study (with one possible

exception) is number of advanced degrees, by either teachers or managers, associated with pupil performance.

If the universities cannot provide central direction, the only other candidates are state governments and the Federal government. Undoubtedly, the state educational establishments and legislatures could provide some direction. In California and New York this has already been accomplished to some extent, merely by appropriating money for large experiments (California) and by attempting to gather comprehensive data sets (New York). More state-funded educational experiments are needed and most states have enough resources to devote some of them to this activity which, when placed in perspective, actually costs very little.

But educational innovation can be expected to benefit the entire nation, not just the schools in one state. If one state engages in this activity an important externality is created; good is being done for the entire society for which citizens of that state are not properly compensated. It is obviously the place of the Federal government to provide central direction. In my opinion, this important role could be performed by an institution similar to the National Institute of Education (NIE), the formation of which is currently being proposed to Congress.*

AN EXAMPLE OF A RESEARCH DESIGN

I visualize the following scheme as an example of the kind of integrated research design which would be possible under the leadership of an NIE. The National Institute of Education would pick a group (or perhaps two groups) of 100 or 150 cooperating school districts over the nation. Districts would range in size from tiny to hugh, averaging perhaps 8 or 10 schools per district and 600 to 800 pupils per school. Each district would be well paid to cooperate as an ongoing "Federal experiment school." For example, the pay could be $50 per pupil for the first three ("set-up") years and $25 per pupil thereafter, plus the privilege of sharing a management

*I find myself in almost complete agreement with Levien's remarks [31] about the needs which the proposed institute could meet.

information scheme and central computer services, such as report card preparation.

During the three planning years, questionnaires and instruments would be designed for all school personnel. Discussions would be held concerning test instruments to be used for the students. Information on socioeconomic background and attitudes would be gathered for each student. Every information-gathering procedure in every district would be precisely the same. There would be as little fanfare as possible about the fact that a school district was chosen as an experimental one. Participating personnel would be instructed to go about their business and try to forget about it.

With this group of cooperating districts, information could be routinely gathered which could be used to make excellent studies, similar (but with much better quality) to those I have described above. Besides this, personnel at the NIE would select promising experiments to test. These could range from large schemes that might radically change the complete school technology to carefully arranged small experiments for such things as alternative instructional strategies. Researchers in universities and elsewhere whose work shows promise would be invited to design further experiments for the experimental schools. Each researcher would have a staff member of the NIE assigned as his co-worker in the project. This would ensure the comparability of all projects, the large single missing ingredient which has made much of the past work (some of which has itself been very good) useless to us.

Such a scheme could, after the passing of a few years' time, allow us to come close to defining educational production functions, including pathbreaking work on the theories of instruction and learning, and, considering the benefits, the plan would not be too costly.

AN ANNOTATED LIST OF MULTIVARIATE STUDIES

Chronologically Arranged by Date of Publication

Mollenkopf, 1956

Mollenkopf, William G., *A Study of Secondary School Characteristics As Related to Test Scores*, Research Bulletin RB-56-6, Educational Testing Service, Princeton, New Jersey, 1956.

This study relates variables obtained from a questionnaire sent to secondary schools to pupil aptitude and achievement performance.

Thomas, 1962

Thomas, James Alan, *Efficiency in Education: A Study of the Relationship Between Selected Inputs and Mean Test Scores in a Sample of Senior High Schools* (unpublished Ph.D. dissertation, microf.), Stanford University Library, 1962.

A study of 206 Project Talent high schools found in communities with populations between 2,500 and 25,000.

Burkhead, 1967

Burkhead, Jesse, Thomas G. Fox and John W. Holland, *Input and Output in Large City High Schools*, Syracuse Univ. Press, Syracuse, New York, 1967.

This is a study of high schools in Chicago, Atlanta, and a selected sample of Project Talent high schools.

Katzman, M. T., 1967

Katzman, M. T., *Distribution and Production in a Big City Elementary School System*, Yale University Library, New Haven, Conn. (unpublished Dept. of Econ. Ph.D. dissertation).

This is a study of schools within the Boston school system.

Cohn, 1968

Cohn, Elchanan, "Economies of Scale in Iowa High School Operation," *Journal of Human Resources*, Vol. 3, No. 4 (Fall, 1968), pp. 422-44.

A study of 377 Iowa high schools.

Hanushek, 1968

Hanushek, Eric A., *The Education of Negroes and Whites* (unpublished Ph.D. dissertation, microf.), Massachusetts Institute of Technoloy Libraries, Cambridge, Massachusetts, 1968.

A study of the relative effects of school and background characteristics of whites in 471 schools and blacks in 242 schools, using data gathered by the U.S. Office of Education's Equal Opportunity Survey.

Bowles, 1969a (Project Talent data)
Bowles, 1969b (Equal Opportunity Survey data)

Bowles, Samuel, *Educational Production Function*, Final Report, U.. Department of Health, Education, and Welfare, U.S. Office of

Education, OEC-1-7-00451-2651, ED 037 590, Harvard University, Cambridge, Mass., February, 1969.

This is a study of the performance of Black twelfth graders; it includes findings from two data sets: Project Talent high schools and the U.S. Office of Education's Equal Opportunity Survey (EOS). Bowles' study is treated as two studies here, with the findings from the Talent high schools labeled (a) and the EOS data (b). The results of the Project Talent study can be found in W. Lee Hansen (ed.), *Education, Income, and Human Capital*, Studies in Income and Wealth No. 35, National Bureau of Economic Research, Columbia University Press, New York, 1970, pp. 11-61.

Fox, 1969

Fox, Thomas G., "School System Resource Use in Production of Interdependent Educational Outputs," *The Joint National Meeting, American Astronautical Society and Operations Research Society*, paper presented at Denver, Colorado, 1969 (mimeo.).

Additional studies done within a simultaneous equation framework of the Chicago high school data used by Burkhead (above).

Kiesling, 1969

Kiesling, Herbert J., *The Relationship of School Inputs to Public School Performance in New York State*, The Rand Corporation, P-4211, Santa Monica, California, October, 1969.

A study of the data for New York State school districts gathered in 1958, 1959, and 1960. Grades 4, 5, 6 were studied. Meaningful relationships were found for 46 of the 89 urban districts studied and these were used for the results described.

Hanushek, 1970

Hanushek, Eric, *The Value of Teachers in Teaching*, The Rand Corporation, RM-6362-CC/RC, December, 1970.

This is a study of the relationship of second and third grade pupils in a medium-sized California school district which is unique in that pupils were matched to individual teachers. Caucasian and Spanish-surnamed children were studied separately.

Kiesling, 1970

Kiesling, Herbert J., *A Study of the Cost and Quality of New York School Districts*, Final Report, Bloomington, Indiana, Project No. 8-0264, U.S. Department of Health, Education, and Welfare, U.S. Office of Education, Washington, D.C., 1970.

A study of grades 5 and 8 from a sample of 86 school districts in New York State for which data were gathered in 1965.

Levin, 1970

Levin, Henry M., "A New Model of School Effectiveness,""*Do Teachers Make a Difference?*, U.S. Department of Health, Education, and Welfare, U.S. Office of Education, OE-58042, Washington, D.C., 1970, pp. 55-78.

A study of pupil data for schools in a large eastern city gathered by the Equal Opportunity Survey. It contains the first use of simultaneous equation techniques in educational model building.

Michelson, 1970
Michelson, Stephan, "The Association of Teacher Resourcefulness with Children's Characteristics," *Do Teachers Make a Difference?*, U.S. Department of Health, Education, and Welfare, U.S. Office of Education, OE-58042, Washington, D.C., 1970, pp. 120-168.

This contains further research with the data used by Levin generated by the Equal Opportunity Survey for a large eastern city.

Averch-Kiesling, 1971
Averch, Harvey, and Herbert J. Kiesling, *The Relationship of School and Environment to Student Performance: Some Simultaneous Models for the Project Talent High Schools*, The Rand Corporation, Santa Monica, California (forthcoming).

This study, still in progress in 1971, compares ordinary and two-stage least-squares techniques for models of pupil performance using grades 9 and 11 in the 775 public Project Talent high schools.

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